CHAPTER 2

REVIEW OF LITERATURE

2.1 Lichenology abroad:

In 1700 A.D., Turnefort designated lichen as a distinct group. Father of plant taxonomy, Carolus Linnaeus reported 80 species of lichen under the 24th class of Cryptogamie-Algae in "Species Plantarum" (1753). Erik Acharius, the last pupil of Linnaeus pioneered lichen taxonomy and is known as the father of lichenology. He described many new genera and numerous new species on the basis of morphological studies in his works "Methodica Lichenum" (1803), "Lichenographia Universalis" (1810) and "Synopsis Methodica Lichenumn" (1814). Majority of the lichenological work has been done in the European countries. Reports on lichen diversity are available from Australia and American regions (Purvis *et al*. 1992). A few survey were aimed at conservation of rare, and endangered epiphytic lichens (Bruteig 1993). Mongkolsuk *et al.* (2012), reported 20 species of *Pyxine* from Thailand, amongst which four viz. *Pyxine boonpragobiana* Kalb & Mongkolsuk, *P. dactyloschmidtii* Kalb & Mongkolsuk, *P. pseudokeralensis* Kalb, Mongkolsuk & Buaruang, and *P. subcoralligera* Kalb, Mongkolsuk & Boonpragob were new to science. Bungartz *et al*. (2013) marked *Cryptothecia* and *Herpothallon* as part of a comprehensive inventory of Galapagos Island. Vaz *et al.* (2014) enumerated 17 lichen species, amongst which *Cladonia rei* Schaer. was declared as a new species from Portugal. Baral (2015) explored Manaslu Conservation Area and Sagarmatha National Park of Nepal and reported 621 lichen species. The family Parmeliaceae dominated the area followed by Physciaceae and Cladoniaceae. Vondrak *et al.* (2015) recorded 230 epiphytic and epixylic species in the Slovakian old-growth beech dominated by Stuzica forest of which 115 species were new to Stuzic. Nascimbene and Marini (2015) documented 124 epiphytic lichen species along elevational gradients from Norway spruce forests. Dathong (2016) reported 54 lichen species belonging to 30 genera and 16 families from Nakhon Ratchasima, Thailand of which 38 species were crustose and16 foliose. Lendemer *et al.* (2016) reported 386 lichen taxa from 49 sites of Dare Regional Biodiversity Hotspot in the Mid-Atlantic Coastal Plain of North Carolina, Eastern North America. Ohmura *et al*. (2016) reported 78 taxa (77 species and a variety) from Mikura-jima and Izu Islands, Central Japan of which *Graphis mikuraensis* Y. Ohmura & M. Nakan. was described as new species. Reynolds *et al.* (2017) reported 106 species under 45 genera of which two were considered as threatened, five at risk and 27 data deficient from 20 Mangrove sites in the upper North Island of New Zealand. Galinato *et al.* (2017) revealed wide variety of lichens ranging from crustose, foliose and fruticose forms from cool temperature and high elevated mountains of Kalinga in northern part of Philippines. *Usnea* sp. was the most commonly found fruticose lichen. Reynolds *et al.* (2017) studied lichens from New Zealand and reported total 106 lichen species under 45 genera from 200 mangrove trees. Joshi *et al.* (2018) reported three new species viz. *Thalloloma nitidum*, *Thelotrema isidiosum* and *T. megasporum* under the family Graphidaceae from Philippines. Theerapat *et al.* (2018) reported *Architrypethelium murisporum* new to Southeast Asia. Lücking *et al*. (2019) studied diversity and community composition of lichens of dry tropical forest remnants in the Atlántico department of Colombia and revealed 61 species, including four new to science and 37 species as new records for Atlántico. Benítez *et al*. (2019) studied lichen diversity in ecological Reserve Arenillas, in El Oro province, southwestern Ecuador and reported 122 epiphytic lichen species collected from 513 trees and were dominated by crustose with 110 species, followed by foliose and fruticose with 11 and 1 species respectively. Suharno *et al*. (2020) revealed 37 species that belong to 24 genera and 11 families on several habitats with varying altitude from 1655 to 2179 m and temperature ranging from 18°-26°C in the Baliem Valley, Jayawijaya, Papua. It was dominanted by species under Parmeliaceae, Cladoniaceae, and Teloschistaceae. Stepanchikova *et al.* (2020) prepared the lichen checklist for the northern shore of the Gulf of Finland in the limits of St. Petersburg, Russia that comprised 469 species. Leavitt *et al.* (2021) studied over 800 lichen specimens in alpine isolated sky Island in Colorado Plateau, USA. Hofmeister *et al.* (2022) recorded 550 epiphytic and epixylic lichen species in Great Britain in eleven hectare forest plots located in old-forest stands in four distinct biodiversity hot spot regions. Belguidoum *et al*. (2022) reported 54 species under 29 genera and 19 families, of which crustose and foliose, were the most common in the urban area of Setif, Algeria. Himelbrant *et al*. (2022) revealed 230 species, including 206 lichenized, 17 lichenicolous, and seven non-lichenized saprobic fungi in the historical territory, Osinovaya Roscha, Russia. Vondrák *et al.* (2022) studied lichen diversity hotspot and refugium for rare species of the Týřov National Nature Reserve (Czech Republic, Central Bohemia). From the study 675 lichens, 35 semilichens, 58 lichenicolous fungi and 19 bark microfungi were reported within 410 hectares of which nine species were new to science, three new to Europe, 55 new to the Czech Republic and 191 species were included in the national Red-list. Lyn *et al*. (2023) revealed highest member from Graphidaceae and least from Lecanoraceae, Mycoporaceae, Pilocarpaceae, Porinaceae, Stereocaulaceae and Strigulaceae from agro forestry centre of the Occidental Mindoro College, Philipines.

2.2 Lichenology in India:

Lichenology in India was initiated by the Europeans since the era of Carl Linneaus. Indian researchers started exploring lichens during later part of the twentieth century which were identified by the European lichenologist. Quraishi (1928) reported 30 species of lichen from Musoorie. In another attempt, Kashyap, Chaudhuri and Chopra in 1931 collected lichens from the Himalayas and were identified by Smith and Zahlbruckner. D.D. Awasthi, laid a strong foundation of lichenology in India during the 1950's. Because of his immense contribution he is considered as the father of Indian lichenology. Institutions like CSIR- NBRI, Lucknow, Agarkar Research Institute, Pune, Botanical Survey of India, Allahabad and Andaman are always in the forefront to sustain lichenology in India and have been providing excellent assistance to foster the budding lichenologist.

Although scientific study of plant science in India is dominated by higher group of plants, lichenology is not a neglected branch of biological science now. Besides taxonomical study, biomonitoring, biodeterioration and bioprospection are some of the important aspects that are gaining much importance in the field of lichenological research. Andaman & Nicobar Islands, Western Ghats and Eastern Himalaya including North-East India are considered lichen diversity hot spots (Nayaka and Upreti 2021). Mountainaineous terrain, moisture laden monsoon winds blowing across the Bay of Bengal, abundant rain in most of the regions of the country throughout the year are some of the facts for the richness of lichen biota in India with high degree of endemism. In India lichens are mostly explored from different foothills of the Himalayas (Upreti *et al.* 2005a). Darjeeling districts, parts of Kumaun and Garhwal Himalayas, Nagaland, Sikkim, Palni and Nirgiri Hills in Western Ghats and Andaman Islands are some of the regions exhaustively explored for lichen diversity. Apparent collections of lichen are done from Andhra Pradesh, Arunachal Pradesh, Assam, Jammu & Kashmir, Manipur, Meghalaya, Orissa, Rajasthan (Reddy *et al.* 2011); Bihar, Madhya Pradesh and Tamil Nadu (Upreti 1998a), and Uttar Pradesh (Nayaka *et al*. 2011). Western Himalayan region have significant contribution on lichen flora of India (Upreti *et al.* 2010a; Sheikh *et al.* 2006; Kumar and Upreti 2008; Srivastava *et al.* 2004).

Lichen diversity from Central India including those growing on monuments of Madhya Pradesh are recorded (Upreti *et al.* 2005; Bajpai *et al.* 2008; Upreti *et al.* 2010b; Reddy *et al.* 2011). The lichen biota from Western Ghats were enumerated by Nayaka and Vinayaka (Nayaka *et al.* 2003, 2004, 2006; Vinayaka *et al.* 2010) and the Eastern Ghats by Shyam *et al.* (2011). Upreti *et al.* (2007) enumerated lichen diversity of Kolkata City from the Gangetic plains and Indian Botanical Garden.

Kumar (2000) studied macrolichens of Kerala during the period 1997-2000 and enumerated 254 species under 43 genera and 18 families of which the family Parmeliaceae dominated the area with 80 species. Khare *et al.* (2009) enumerated 51 species of terricolous lichens in the Himalayan region of India. The Western Ghat is regarded as one of the 'Biodiversity Hotspot' regions of India that supports 45% of the total lichens in India with 253 species endemic to the region (Sudarshan *et al.* 2010). Vinayaka *et al.* (2011) studied epiphytic lichen of Koppa taluk, central Western Ghats in semi-evergreen and deciduous forests and reported 36 species belonging to 15 genera and 9 families. *Graphina* sp*, Graphis celata, Heterodermia incana, H. pseudospeciosa, Lecanora indica, Porina americana* and *Leptogium burnetiae* are found growing on *Randia dumetorum*, having moderate bark texture. Balaji and Hariharan (2013) prepared checklist of macrolichen from dry deciduous forest, moist deciduous forest and western tropical evergreen forest vegetation within Bolampatti II forest range, Western Ghats, India. The number of species accounted to 103 of which the dominant order, family and genus were Lecanorales (47 species), Parmeliaeae (40 species) and *Usnea* (15 species) respectively. Shukla *et al.* (2014); Mishra and Upreti (2016) reported lichen diversity from Uttarakhand. Goni *et al.* (2015) prepared checklist of 356 lichen species from Jammu and Kashmir. Panda *et al.* (2017) studied manglicolous lichens from the mangrove forests of Bhitarkanika Wildlife sanctuary and National Park of Odisha and enumerated 49 species within 26 genera and 14 families of which *Chrysothrix* was the most commonly reported species. Ingle *et al*. (2017) for the first time reported *Polymeridium cinereonigricans* (Vain.) R.C. Harris, *P. pleurothecium* R.C. Harris and *P. submuriforme* Aptroot from India. Mariraj *et al.* (2018) reported fruticose species, *Usnea dasaea* Stirt. from Tamil Nadu. Bharadwaj (2019) reported *Graphis ajarekarii* Patw. and C. R. Kulk, and *Ramalina leiodea* (Nyl.) Nyl. from Andhra Pradesh and Orissa respectively. Mishra *et al*. (2020) reported 382 Pyrenocarpous lichens under 49 genera and 12 families from India. Moist and warm climatic conditions of the Eastern Himalaya favours rich diversity of Pyrenocarpous lichens with about 295 species. Punjani *et al*. (2021a) studied lichens from dry deciduous and scrub thorny forests of Shivrajpur Coast, Devbhoomi Dwarka, Gujarat state and revealed 16 species under nine genera within five families of which eight were new to Gujarat. In another study, Punjani *et al.* (2021b) enumerated 13 species as new records for the state from Alang-Sosiya Shipyard. Saraswat *et al*. (2023) reported 19 species under 16 families and 9 genera from the monuments of Rajasthan, of which eight species were new to the state and a species to India. The dominant growth form was squamulose followed by sub- fruticose, crustose and leprose. Rajaprabu and Ponmurugan (2023) reported 1500 lichen taxa from the Western Ghats of which Tamil Nadu is the 2nd richest area with 938 species.

2.3 Lichenology in Northeast India:

Eastern Himalayan region covering most of the North-Eastern states of India is a part of the Indian Himalayan biodiversity hotspot and truly represents one of the biodiversity rich regions in the world, a paradise (Myer *et al.* 2000; Mittermeier *et al.* 2005). The region has always been a focus of distinctive courtesy to the plant explorers and nature lovers (Singh *et al.* 2018). This is the richest lichenogeographic regions in India (Singh and Sinha 1997). Lichen samples collected from Northeast India and Darjeeling district by G. Watt were described by Stirton (1876, 1879). Lichen diversity of Eastern Himalaya is rich and several workers reported lichen species from the regions.

Singh (1981) and Singh (1984) explored lichen diversity from Manipur. Singh and Sinha (1994) enumerated lichen flora of Nagaland. Singh (1999) reported 843 species under 150 genera from Eastern Himalayan region including Assam, Meghalaya, Mizoram, Manipur, Nagaland and Tripura. Singh and Bujarbaruah (2001) and Singh *et al.* (2005) studied lichens of Arunachal Pradesh. Pinokiyo (2004) reported 98 foliicolous lichen from the state of Arunachal Pradesh. Sinha and Singh (2005) described 320 species of macrolichens under 72 genera from Sikkim. In another study, Pinokiyo (2006) reported 37 follicolous lichens from the state. Sinha and Jagadeesh Ram (2011) reported 506 species under 128 genera from Sikkim. Singh (2011) in his work, "Lichen flora of Nagaland," reported 346 species of lichen; the genus *Awasthiella* was discovered as new to science from Manipur. Singh *et al*. (2018) reported 1049 lichen species from Eastern Himalayan region. This contributes approximately 41.29% of the total Indian lichen biota and 19.7% of the total Indian endemic lichen species. The family Graphidaceae and the genera *Graphis* is dominant in the Eastern Himalayan region. Thangjam *et al*. (2019) recorded 20 lichen species under 15 genera and 10 families from central part of Murlen National Park, Mizoram and Parmeliaceae was the dominating family. In another attempt, Thangjam *et al*. (2022) reported 30 lichen species with nine of the species new to the state Mizoram. Bajpai *et al.* (2022) reported 686 lichen species belonging to 185 genera and 52 families from Arunachal Pradesh. Further enumeration of lichens from diverse places of North East India is being extended.

2.4 Lichen Diversity in Assam:

Vegetation of Assam is comprised of tropical evergreen, semi-evergreen, deciduous forest types and grasslands (Dey *et al.* 2015) and dominated with tropical lichen vegetation (Singh *et al.* 2018). Stirton (1881) was the pioneer to work on lichenology of Assam and described 39 lichen species from tea plants. Innumerable literatures are available on lichen diversity from the state Assam (Santesson 1952; Awasthi 1961; Patwardhan and Kulkarni 1977; Parwardhan and Nagarkar 1980; Nagarkar and Patwardhan 1981, 1982; Nagarkar *et al.* 1988; Makhija and Patwardhan 1993; Pant and Upreti 1993; Divakar and Upreti 2005; Rout *et al*. 2005, 2010, 2012; Awasthi 2007; Tewari and Upreti 2008; Hazarika *et al.* 2011; Mishra *et al*. 2011, 2019; Das *et al*. 2012, 2013; Sharma *et al.* 2012; Gupta *et al*. 2013, 2019, 2020; Daimari *et al*. 2014, 2017, 2021; Dey *et al*. 2015; Choudhury *et al*. 2016; Gupta and Sinha 2018; Joshi *et al.* 2018b; Gogoi *et al*. 2019, 2020; Kondratyuk *et al.* 2020; Ngangom *et al.* 2020; Behera *et al*. 2021; Islary *et al*. 2021) are some prominent workers on the lichens of this region. Gogoi *et al.* (2022a) provided a lichen checklist of Assam that incorporated 657 lichen species under 146 genera 41 families. The state Assam is represented by Graphidaceae as the dominat family with 148 species of which the genus *Graphis* recorded 70 species followed by Pyrenulaceae with 84 species and genus *Pyrenula* with 72 species. Lichen diversity is reported from 20 of the 35 districts of Assam. The district Cachar records highest number of lichen with 214 species followed by Nagaon, Sonitpur and Dima Hasao with 203, 181 and 143 species respectively. Islary *et al*. (2022a, 2022b and 2022c) reported 21 lichen species as new record to Assam and 10 species new to India from Kokrajhar district of Assam. Gogoi *et al*. (2022b) reported 31 lichen species under 21 genera and 14 families from Nagaon district of Assam, of which *Tylophoron protrudens* Nyl. was a new record to Assam. Choudhury and Phukan (2023) reported 46 lichen species under 23 genera and

13 families from Doboka Reserve Forest, Hojai of Assam. With these studies as of now Assam is represented by more than 689 lichen species and Graphidaceae dominates the area followed by Pyrenulaceae. The altitude and monsoon winds loaded with moisture blowing across the Bay of Bengal, humid climate, abundant annual rainfall, topography of the North-East Indian regions offers suitable conditions for the growth of lichens. The regions are rich in lichen diversity however most of the regions are untouched, therefore many more explorations are needed to document them before they become extinct due to present day deforestation and other anthropogenic activities.

As per the earlier report by Gupta and Sinha (2018), seven lichen species viz. *Graphis subasahinae* Nagarkar & Patw., *Lecanora alba* Lumbsch, *Lecanora helva* Stizenb., *Parmotrema saccatilobum* (Taylor) Hale, *Protoparmelia hesperia* (Kantvilas & Elix) Kantvilas, Papong & Lumbsch, *P. acutalis* R.C. Harris and *Letrouitia flavocrocea* (Nyl.) Hafellner & Bellem. were reported from various parts of Dhubri district. There after there is no report on lichenology from the district.

2.5 Lichen compounds and their antimicrobial activity:

Since time immemorial, plants have been providing ecological services to mankind and animals as well by providing food, timber and medicine. However, plants are vulnerable to etiology of various diseases caused by micro-organisms. Some pathogens are host specific and can cause great loss to economy. The chemical fungicides or bactericides generally used in mitigating the diseases have many demerits like residual problem, effect on non-target organisms and development of resistant varieties (Cown 1999; Poornimal and Sarathambal 2009).

Lichen extracts and their purified compounds have been documented as potent antimicrobial agents that inhibit a wide range of bacterial and fungal pathogens (Yilmaz *et al*. 2004; Turk *et al*. 2006; Canarasan *et al*. 2006; Candan *et al*. 2006; Vinayaka *et al*. 2009; Kekuda *et al*. 2011; Kambar *et al*. 2014; Prabhu and Sudha 2015). It is evident from the literatures that lichen secondary metabolites are very unique and potent to be utilized against pathogenic diseases in plants as well as in human and other animals.

Generally fungal species and gram-negative bacteria are more resistant than gram-positive bacteria because of the composition of their cell wall (Nostro *et al.* 2000). Cell wall of gram-positive bacteria with peptidoglycans, teichoic acids are more permeable than gram-negative bacteria with peptidoglycan, lipopolysaccharides and lipoproteins (Heijenoort 2001; Ranković and Mišić 2008) and fungal cell wall with polysaccharides such as chitin and glucan (Farkaš 2003).

Karabulut *et al*. (2015) reported great economic loss in agriculture and food industry during the post harvesting period of crops due to pathogenic fungi. The in vitro 96% alcoholic extracts of *Evernia prunastri, Pseudevernia furfuracea var. furfuracea* and *Parmelia sulcata* were investigated against phytopathogens *Aspergillus niger, Botrytis cinerea, Fusarium culmorum, F. solani, Macrophomina phaseolina*, *Penicillium expansum* and *Rhizoctonia solani* and their growth of inhibition was recorded. Babiah *et al.* (2014, 2015) evaluated methanolic, acetone and chloroform extracts of *Heterodermia leucomoles* and *Parmotrema reticulatum* against *Aspergillus niger, A. flavus, Fusarium oxysporum, F. solani* and *Colletotrichum falcatum.* Maximum inhibition was shown by acetone extracts of *P. reticulatum* against *F. solani* (17.00 mm) higher than standard control Ketoconazole (15 mm) and the lowest activity was shown by chloroform extract of *P. reticulatum* against the same pathogen. Kekuda *et al*. (2015) tested antifungal potential of lichen extracts of *Dirinaria consimilis, Ramalina hossei, R. pacifica, Parmotrema reticulatum*, *Heterodermia obscurata* against phytopathogens viz. *Colletotrichum capsici, Fusarium oxysporum* f. sp. *zingiberi, Alternaria alternata and Aspergillus flavus*. Tested lichen species have phytochemicals like Atranorin, chloroatranorin, salazinic acid, consalazinic acid, usnic acid, zeorin and sekikaic acid in them. Shivanna *et al.* (2016) revealed fungicidal effect of methanol, ethyl acetate and acetone crude extracts of macrolichens viz. *Heterodermia comosa, Parmotrema margaritatum, Pseudocyphellaria aurata, Ramalina farinacea* against phytopathogens *Fusarium oxysporum, F. solani* and methanolic extract of *R. farinacea* was found more effective. Devi *et al*. (2016) studied propanolic, methanolic, acetone and petroleum ether extracts of *Ramalina conduplicans* Vain against phytopathogens *Aspergillus flavus, A. niger, Colletotrichum falcatum, Fusarium oxysporum, F. solani, Rhizoctonia bataticola, Trichoderma lignorum* and *Yeast* sp. Plaza *et al.* (2017) studied antifungal activity of ethanolic extract of *Cladonia* aff. *rapii* against *Candida alibicans, C. glabrata, C. krusei, C. parapsilosis, C. tropicalis* and *Cryptococcus neoformans.* The dichloromethane extract showed lowest MIC and MFC values against *C. neoformans* and no activity was observed against aqueous extract. Ankith *et al.* (2017) revealed potent antimicrobial activity of *Ramalina pacifica* Asahina, *R. conduplicans* Vain and *R. hossei* Vain, rich in bioactive compounds viz. usnic acid, salazinic acid, sekikaic acid against *Alternaria* sp., *Bacillus cereus, B. subtilis, Curvularia* sp., *Escherichia coli, Fusarium* sp., *Pseudomonas aeruginosa*. *Ramalina* sp. exhibit potent antibacterial and antifungal activity due to presence of bioactive compounds such as usnic acid, salazinic acid and sekikaic acid. Anupama *et al.* (2017) revealed the presence of carbohydrates, coumarins, flavanoids, phenols, saponins, tannins, terpenoids, minerals, crude fibre and crude protein in *Parmotrema tinctorum*. Vinayaka *et al.* (2017) and Kekuda *et al*. (2017) revealed antifungal activity of methanolic extracts of *Coccocarpia erythroxyli* (Spreng.) Swinsc. ow & Khrog and *Heterodermia incana* (Stirt.) D.D. Awasthi against phytopathogens viz. *Alternaria* sp., *Curvularia* sp. and *Fusarium* sp. Gazo *et al.* (2019) tested acetone extract of *Ramalina farinacea, R. roesleri, and R. nervulosa* against phytopathogens viz. *Colletotrichum capsici, C. gleosporioides, Fusarium oxysporum, F. solani,* and *F. verticillioides*. Bioactive compounds found in these lichens are barbatic, constictic, confumaprotocetraric, consalazinic, divaricatic, hypoprotocetraric, isonotatic, norstictic, perlatolic, protocetraric, stictic, salazinic, sekikaic and usnic acids. Ahmed *et al*. (2020) reported antimicrobial potency of the acetone, methanol, petroleum ether and diethyl ether extracts of *Dirinaria applanata, D. picta, D. papillulifera* against *Staphylococcus aureus* and *E. coli*. Sahoo *et al*. (2021) revealed antimicrobial activity of methanolic and acetone extracts of the lichen species viz. *Parmotrema andium* and *Dirinaria applanata* against *Aspergillus niger, Bacillus subtilis, Candida albicans, Escherichia coli, Fusarium oxysporum, Penicillium verrucosum, Staphylococcus aureus, Vibrio cholera. D. applanata* showed better result compared to *P. andium*. Yadav *et al.* (2021) revealed antfungal activity of methanol, ethanol, ethyl acetate, acetone extracts of *Usnea longissima* against *Aspergillus niger, Candida albicans* and *Fusarium oxysporum*. Paguirigan *et al.* (2022) studied potential antimicrobial activity of lichen acids- baeomycesic acid, lecanoric acid, squamatic acid, thamnolic acid, lobaric acid, salazinic acid, usnic acid and vulpinic acid against *Alternaria alternata, A. mali, Botrytis cinerea, Botryosphaeria dothidea, Clavibacter michiganensis subsp. michiganensis, Colletotrichum gloeosporioides, Diaporthe actinidiae, Dickeya chrysanthemi, D. eres, Erwinia pyrifoliae, Fusarium oxysporum f. sp. lycopersici, Pseudomonas syringae pv. actinidiae, Pythium ultimum, Ralstonia solanacearum, Rhizoctonia cerealis, R. solani, Sclerotinia sclerotiorum, Xanthomonas arboricola pv. pruni, X. euvesicatoria, X. citri.* Pradhan *et al.* (2022) estimated the concentration of alkaloids, flavonoids, total saponins, steroids, tannins and terpenoids in *Dirinaria aegialita* and *Parmotrema praesorediosum*. Crude extracts were tested for antioxidant properties, antimicrobial activity against *Aspergillus niger, Bacillus subtilis, Candida albicans, Pseudomonas aeruginosa, Staphylococcus aureus* and *Trichoderma harzianum* and anticancer properties using breast cancer cell lines. *Dirinaria aegialita* is revealed to have better potential as anticancer and antioxidant properties. *Parmotrema praesorediosum* had better antimicrobial potential. Ureña-Vacas *et al.* (2023) reported that lichen compounds atranorin, fumarprotocetraric acid, gyrophoric acid, lecanoric acid, physodic acid, protocetraric acid, stictic acid and usnic acid exhibit strong antimicrobial properties against human, animal and plants pathogens. Recently green synthesis of nanoparticles with antibacterial, antibiofilm, antiquorum sensing, antimotility, and antioxidant activities has gain momentum (Alavi *et al.* 2019; Yang *et al*. 2023). Table 1 represents the various compounds found in the lichen species considered for its evaluation against some phytopathogenic microorganisms in the present study.

Table 2.1: Secondary metabolites present in the macrolichen species

Sl. no.	**Lichen species**	**Lichen compounds**	**References**
1	*Dirinaria appalanata* (Fèe) D.D. Awasthi	Alkaloid, Atranorin, carotenoids, divaricatic acid and its ester derivatives, 1β-acetoxy 3β-hydroxy-21α–hopan-29-oic acid, hopane-3β, 6β 21α- triol, 2-O′-methylnordivaricatic acid, Tannin, terpene, flavonoid, Ellagic acid, 3,3′-di-O-methyl ether, 5,5′-dehydrodiferulic acid, 3,3′,4-tri-O-methylellagic acid, 5′-methoxydehydrodiconiferyl alcohol, gaigrandin, terpecurcumin Q, ergosteryl acetate, taxuspine C and dichrostachine F, methyl hematommate, methyl β-orcinolcarboxylate, ramalinic acid, lichenxanthones, tannins, and terpenes such as the novel hopane 1β-acetoxy-21α hopane-3β, 22-diol	Elkhateeb *et al*. (2020); Tuan *et al.* (2020); Tatipamula *et al*. (2019); Ahmed *et al.* (2017)
2	*Dirinaria consimilis* (Stirt.) D.D. Awasthi	Atranorin, Antarvediside A , Antarvediside B, chloroatranorin, 3β-acetoxyhopane-1β, 22-diol, 4-O-dimethyl, sekikaic acid, homosekikaic acid, Divaricatic acid, 2′-O-methyldivaricatic acid	Prashith *et al*. (2015); Tatipamula *et al.*, (2019)
3	*Dirinaria papillulifera* (Nyl.) D.D. Awasthi	Divaricatic acid	Awasthi (2007)

4	*Dirinaria picta* (Sw.) Clem. & Shear	Divaricatic acid, Carbamic acid, propionic acid, glycolic acid, 1,3-hydroxy-3-methylglutaric acid, ribonic acid, gluconic acid, β-amyrone and various sugar and amino acid moieties, Naphthalene, acenaphthylene, acenaphthene, anthracene, phenanthrene, fluoranthene, pyrene, benzo anthracene and chrysene, 5-methyluridine, ethyl syringate, δ-guanidinovaleric acid, orsellinic acid, ethyl ester, 3,4-dihydroxyphenylvaleric acid, usnic acid, ethyl everninate, 2-O-methylatranorin	Haung *et al*. (2013); Samdudin *et al*. (2013); Tatipamula *et al*. (2019)
5	*Parmotrema saccatilobum* (Taylor) Hale	Atranorin, Protocetraric acid	Awasthi (2007); Moriano *et al*. (2015)
6	*Pyxine cocoes* (Sw.) Nyl.	Flavonoid, lichexanthone, saponin , tannin, triterpenes	Awasthi, (2007); Khan *et al*. (2019)
7	*Pyxine reticulata* (Vain.) Vain.	Triterpenes	Awasthi (2007)

Fractionated extraction can be used because of different solubility of the lichen compounds in different solvents. The approved sequence is hexane-diethyl ether-acetone-methanol (Ribár *et al*. 1993). Polar solvent methanol has the capacity to dissolve maximum amount of desired active constituents. The solvent dissolve maximum hydrophilic compounds. Hexane heavily dissolve lipophilic compounds (Sasidharan *et al.* 2011).

2.6 Research Gap:

Except for the study by Gupta and Sinha (2018) extensive survey of the region for lichenology is lacking. Moreover, people of this region are largely dependent on agriculture for their livelihood. Pathogens of fungal, bacterial origin pose threat to many economically important crop plants causing various diseases.

Therefore, the present work was undertaken to make a comprehensive and systematic effort to document the lichen diversity from the underexplored areas of the district. Literature review has generated a passion to workout with methanol and hexane extracts of macrolichens, collected from the district against some bacterial and fungal pathogens infecting economically important crop plants which will lead to human welfare and development.